



The activation of embedded words in spoken word recognition



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ABSTRACT

How do listeners understand English words that have shorter words in them? We tested six types of embedded words, varying their positions in carrier words and their proportions of carrier words. In auditory-auditory priming experiments, isolated embedded words (e.g., *ham*) primed their targets under optimal conditions, when they were compressed/expanded, and under cognitive load. Within carrier words (e.g., *hamster*) presented under optimal conditions, the same set of embedded words produced priming only when they were at the beginning of, or comprised a large proportion of the carrier words. No priming was found when the carrier words were compressed/expanded, were presented with one segment replaced by noise, or under cognitive load. The results suggest that both embedded position and proportion play important roles in embedded word activation, but that such activation only occurs under unusually good conditions.

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Introduction

Unlike printed words, spoken words unfold over time. To understand a spoken word, listeners need to map the unfolding acoustic waveform to the lexical representations stored in the mental lexicon. In the literature, there is a consensus that multiple lexical candidates are activated in parallel as the speech stream flows forward. These lexical hypotheses are narrowed down until only a single candidate is consistent with the incoming acoustic information, and a spoken word is then recognized. The present study investigates which lexical hypotheses are activated during spoken word processing. Specifically, we examined whether the meanings of unintended candidates that only match part of the speech signal are accessed, and whether the processing of these candidates changes as the listening conditions become more challenging.

Models of spoken word recognition

Models of spoken word recognition make different claims about lexical activation. The original version of the Cohort model (Marslen-Wilson & Welsh, 1978) emphasized the importance of word onsets in activating lexical candidates. When the first speech segment is heard, a set of lexical candidates – words that begin with the same segment (the cohort) – are activated simultaneously. Lexical candidates are deactivated if they no longer match the unfolding speech input, until only one candidate remains. For instance, hearing the sound /kæ/ in “capital” will activate words like “cattle”, “captain”, and so on. The word “capital” will not be recognized until the fourth phoneme (/l/) occurs, because this is the point when “capital” differs from the other candidates. Words that do not share the onset will not be activated.

Later models agree with the Cohort model that multiple candidates compete for recognition, but they differ in the emphasis on the role of word-initial information. Models such as TRACE (McClelland & Elman, 1986) and

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Shortlist (Norris, 1994) treat lexical access as a continuous process, and allow lexical candidates beginning at different points along the speech signal to be activated. They assume that lexical candidates compete with each other via lateral inhibition. The one that is the most similar to the speech signal usually has the strongest activation and will win the competition. Because candidates that share onsets become activated early in processing, they will inhibit candidates that are activated later. Therefore, although hearing “beaker” will not only activate “beetle”, but also “speaker” as the speech signal continues (Alloppenna, Magnuson, & Tanenhaus, 1998), the activation for the rhyme competitor will be much weaker. In addition, the Shortlist model also emphasizes the importance of stress, giving candidates that start at the onset of a strong syllable extra weight over those that do not. Some models, in contrast, give word onset a less prominent role. For instance, the Neighborhood Activation Model (Luce & Pisoni, 1998), based primarily on monosyllabic words, emphasizes the global similarity between a candidate word and the speech signal, without taking into account whether the shared phonemes occur early or late in the word.

Embedded word activation

The different dynamic properties of word activation across models produce different expectations for how the speech system will recognize spoken words that have other words embedded in them. Such embedding is a very common phenomenon in English. More than 80% of multisyllabic English words have shorter words within them (McQueen, Cutler, Briscoe, & Norris, 1995). For example, “captain” has the word “cap” embedded at the beginning, “trombone” has the word “bone” embedded at the end, and “catalog” has “cat” and “log” embedded at the beginning and at the end. These embedded words are not intended by the speaker but their phonological information is actually presented in the speech signal. Do listeners consider the meaning of these embedded words when understanding utterances? If they do, do the position of the embedded word, and its size relative to the carrier word, affect the likelihood and/or level of the embedded word’s activation?

According to TRACE and Shortlist, initial embedded words will be activated while hearing the carrier word, because they overlap at an early position. Final embedded words are less likely to get activated, because they have a temporal disadvantage: By the time the final embedded word arrives, the carrier word will usually be activated enough to suppress the final embedded word effectively (Frauenfelder & Peeters, 1990). Final embedded words that share more phonemes with the carrier word (i.e., comprise a relatively large portion of the carrier word) will have a better chance to get activated than those that share fewer phonemes (Bowers, Davis, Mattys, Damian, & Hanley, 2009). The Neighborhood Activation Model, however, emphasizes similarity more than position. Therefore, it predicts similar results for initial and final embedded words (Tanenhaus & Brown-Schmidt, 2008).

A number of studies have investigated the effect of position of an embedded word by testing monosyllabic words embedded in two-syllable words either in initial position (e.g., “ham” within “hamster”), or in final position (e.g., “bone” within “trombone”). A few studies have tested monosyllabic words embedded in other monosyllabic words (e.g., “cow” within “couch” and “ram” within “pram”). The results of these studies have been somewhat inconsistent.

Cross-modal priming studies have found no evidence for the activation of monosyllabic words embedded at the beginning of two-syllable carrier words (Marslen-Wilson, Tyler, Waksler, & Older, 1994). For example, listening to a prime word did not facilitate lexical decisions on the initial embedded word within the prime (Marslen-Wilson et al., 1994). Visual-world studies using eye-tracking techniques, however, showed that embedded words were at least briefly activated (Salverda, Dahan, & McQueen, 2003; Salverda et al., 2007; Shatzman & McQueen, 2006). For instance, when participants heard “hamster”, they tended to look more at a picture of “ham” than to look at an unrelated picture (Salverda et al., 2003).

For monosyllabic words embedded at the end of two-syllable carrier words, the results are also quite varied. Positive evidence for their activation comes from studies using cross-modal priming (Isel & Bacri, 1999; Luce & Cluff, 1998; Shillcock, 1990; Vroomen & de Gelder, 1997), picture–word interference (Bowers et al., 2009), and ERPs (van Alphen & van Berkum, 2010, 2012). The results suggest that activation is more likely to be observed when embedded words are in a stressed syllable (Gow & Gordon, 1995; Prather & Swinney, 1977), and when they are aligned with syllable boundaries (Bowers et al., 2009; Vroomen & De Gelder, 1997). However, other studies failed to observe any priming effects or even observed inhibitory priming effects using stimuli with stressed final embedded words that were complete syllables. Some of these studies used cross-modal priming (Marslen-Wilson et al., 1994; Norris, Cutler, McQueen, & Butterfield, 2006), and some used auditory–auditory priming (Macizo, Van Petten, & O’Rourke, 2012).

Only a few studies have tested monosyllabic words embedded in monosyllabic carrier words. Using cross-modal priming, Vroomen and de Gelder (1997) found no priming for either initial or final embedded words, suggesting that segmentation cues play a critical role in activating the embedded word. However, Bowers et al. (2009), using picture–word interference, found naming interference for both initial and final embedded words. The authors suggested that the degree of overlap between the embedded word and the carrier word plays a key role, with positive results for embedded words that comprise a relatively large portion of the carrier word. We will be examining this hypothesis in the current study.

To summarize, the literature on embedded word activation is contradictory, and there currently is no clear conclusion about the effect of embedded position, and how it may interact with the degree of overlap between the embedded word and the carrier word. Essentially all of the previous work has employed monosyllabic embedded words. This

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